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AN EOCENE FLORA IN GEORGIA AND THE INDICATED PHYSICAL CONDITIONS[1]

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(WITH TWO FIGURES)

Eocene plants have been thus far unknown along the Atlantic border, the most easterly known flora of this age having been that of the so-called Eolignitic of the Mississippi embayment, which while abundant is for the most part uncollected and undescribed. Contrasted with this paucity of eocene plants in the east, the western interior Eocene has a flora which in number of species probably exceeds the sum total of all the later tertiary floras of North America. There are also a number of eocene floras along the Pacific coast and in the far north as far as Alaska, the mouth of the Mackenzie River, and Greenland.

The following brief paper is concerned with a most interesting eocene flora of Claiborne age recently discovered, and studied by the writer in connection with the cooperative investigation of the coastal plain in charge of Dr. T. WAYLAND VAUGHAN of the U.S. Geological Survey. These notes partake of the nature of an abstract of this study, which will eventually be published in full by that organization.

The localities are all in eastern Georgia, where there is a marked transgression of the Claiborne sediments, burying all traces of Upper Cretaceous or earlier Eocene deposits and coming to rest upon beds of Lower Cretaceous age or even in some instances upon the crystalline rocks of the eastern Piedmont. The bulk of the plants come from the vicinity of Grovetown, about seventeen miles west of Augusta near the southeastern border of Columbia County. In this area the deposits, which consist for the most part of porous laminated light-colored clays alternating with heavy beds of sand, and more rarely beds of lignite, occupy a pre-Claiborne estuary eroded in the Lower Cretaceous and outcropping as a narrow tongue only two or three miles in width, and extending from the main body of the Claiborne deposits in Richmond County in a northwesterly direction for a distance of about eighteen miles.

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The plants are intimately associated with a few estuarine and shallow water marine invertebrates, such as *Modiolus*, *Ostrea*, *Nucula*, *Leda*, *Cytherea*, etc., which fully corroborate the age of the deposits derived from the study of the flora, where the data for correlation, in the absence of known Claiborne floras, consisted of comparisons with geographically remote floras like those of the Green River beds of Wyoming and those of the Paris basin and southern England. There are certain features, however, notably a marked indication of a rise in temperatures and increased humidity, which, in so far as they are known, characterize middle eocene floras everywhere. This is known to be the case in America, it is markedly shown in the floras of England and France, and is emphasized in the numerous late eocene floras from a large number of arctic localities.

Among the forms collected from the Georgia Eocene are new species of *Acrostichum*, *Arundo*, *Castanea*, *Conocarpus*, *Dodonaea*, *Ficus*, *Malapoenna*, *Momisia*, *Pisonia*, *Potamogeton*, *Rhizophora*, *Sapindus*, *Terminalia*, and *Thrinax*, including the first fossil occurrence of species of *Conocarpus*, *Momisia*, and *Thrinax*.

The foregoing forms represent twelve families and include one fern, three monocotyledons, and ten dicotyledons. No gymnosperms, which are usually represented in European Lutetien floras by at least the genus *Podocarpus*, have been discovered. It will be observed that only two forms, the *Castanea* and the *Potamogeton*, are not coastal forms, and the latter is an aquatic whose presence associated with coastal swamp or strand plants is not difficult to explain. The *Castanea* then apparently represents the only upland type preserved in this flora, and as it is not common, the presumption is strong that it was brought down to the basin of sedimentation by some eocene river, most likely by the river which originally occupied the trough of the subsequent estuary.

Turning to the remaining twelve species, we may enumerate with profit their closest allies in the existing flora. The *Acrostichum* is represented by *A. aureum* Linn., the *Arundo* by *A. Donax* Linn., the *Conocarpus* by *C. erectus* Linn., the *Dodonaea* by *D. viscosa* Linn., the *Ficus* by various tropical American figs, the *Malapoenna* by *M. geniculata* (Walt.) Coulter, the *Momisia* by *M. aculeata* (Sw.) Kl., the *Pisonia* by *P. macranocarpa* Donnell Smith, the *Rhizophora* by *R. Mangle* Linn., the *Sapindus* by *S. saponaria* Linn., the *Terminalia* by *T. phaeocarpa* Eichler, and the *Thrinax* by various West Indian species of that genus.

When we consider the habitat of these modern forms and that of their allies, we find that they inhabit the tidal nipa swamps of the orient, the mangrove swamps of the orient and the occident, the beach jungle of the strand, or the landward side of coastal sand dunes in the tropics. Nearly every one of the fossil species is represented by forms found in the existing flora of the Florida keys or along the shores of peninsular Florida, some like *Conocarpus* flourishing equally well on either muddy or sandy shores. Every species (except *Castanea*) is represented in the American tropics, and four of these existing representatives (*Conocarpus*, *Dodonaea*, *Rhizophora*, and *Sapindus*) range northward to Bermuda in the path of the gulf stream. In looking over SCHIMPER's classical *Indo-malayan strand flora*, the following forms, which are strictly comparable to the Georgia eocene plants, were noted as being more or less prominent elements in the oriental strand flora: *Acrostichum* (*Chrysodium*, 1 sp.), *Dodonaea* (1 sp.), *Eugenia* (2 species which are represented in the west African and American tropics by the allied genus *Conocarpus*), *Ficus* (1 sp.), *Malapoenna* (*Litsaea*, 1 sp.), *Pisonia* (4 sp.), *Rhizophora* (2 sp.), *Sapindus* (1 sp.), and *Terminalia* (1 sp.). Of these forms the *Sapindus*, *Terminalia*, *Dodonaea*, *Ficus*, *Malapoenna*, and *Pisonia* are more particularly elements of the littoral forest (beach jungle of KURZ, *Barringtonia* formation of SCHIMPER), while the others are integral members or rather intimately associated with the mangrove or the nipa associations. It is really remarkable to what an extent the identified elements in the Claiborne flora corroborate one another and definitely denote the character of their habitats, which were, on the one hand, mangrove swamps at certain points where the conditions were favorable, and elsewhere the vegetation of the rain forest which clothed the sandy beaches or was developed behind dunes, which possibly formed the highest inner margin of the beach in places.

Certain rather definite climatic deductions appear to be justifiable from the foregoing facts. None of the modern representatives of this eocene strand flora flourish north of the winter isotherm of about 50° F., and the majority do not occur north of the winter isotherm of 60° F. None of the fossil forms, except possibly the *Potamogeton*, the modern species of which range over a great many degrees of latitude, or the *Castanea*, which likewise has a wide range, would be expected to occur outside of the areas where the modern subtropical rain forests are developed. We would expect the Claiborne climate in the area under discussion, at least at low elevations along the coast and in proximity to the eocene gulf stream, to have been uniformly humid with an abundant and evenly distributed rainfall. The temperature would have been uniform, not necessarily extremely hot, and any degree of winter cold would have been fatal.

These considerations are in a large measure corroborated by what we find to have been the conditions in Europe at this time. It is well known that the middle eocene floras of Europe show many tropical characters absent in the earlier Eocene. These first become marked in the fruits from the London clays and the leaves from Alum Bay and in homotaxial deposits on the continent, and while it was once the fashion to see Australian affinities in these floras, they show closer affinities with the modern floras of Malaysia and tropical America. The accompanying sketch map (fig. 1) will bring this out very well. It shows the area of distribution of the modern genus *Nipa* and the eocene genus *Nipadites*, which is indistinguishable from the modern *Nipa*. The latter has a single species inhabiting the tidal waters of the Indian Ocean, ranging from India through the Malay Archipelago to the Philippines, and vying with the mangroves for possession of the tidal flats. It produces clusters of large floating fruits, and it is exactly similar in both form and structure to the fossil fruits which form the basis for the genus *Nipadites*. As the map shows, these tropical or subtropical floras ranged northward in Europe at this time to southern England, or to about the latitude of Newfoundland on this continent, and these eocene *Nipa* swamps furnished a congenial habitat for one or more species of *Acrostichum* closely allied to that of Georgia, and other forms are not wanting. In the Paris basin a species of *Pandanus* is associated with the *Nipadites*, while at Bournemouth *Gleichenia* and various tropical Polypodiaceae occur. The Lutetien stage of the Eocene in Europe and the Claiborne stage in America are both characterized by a remarkable transgression of the sea, the approximate shore line of the Claiborne sea being shown on the accompanying map (fig. 2). This map makes no pretence to exactness, which would be impossible on so small a scale map, even if the areal extent of the Claiborne deposits were accurately known. What it is intended to illustrate is the relation of land to sea and the line of advance of the flora which was necessarily along the shore from equatorial America, where undoubtedly the representatives of this flora flourished during the whole of the Tertiary.

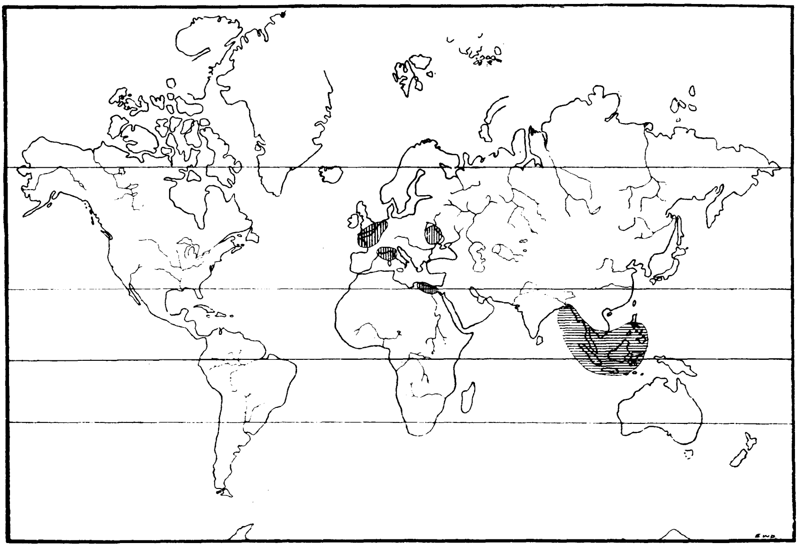

FIG. 1.—Sketch map showing geographical distribution of the existing genus *Nipa* Thunberg and the eocene genus *Nipadites* Bowerbank; horizontally lined area shows single existing species; vertically lined area shows eocene species.

In studying the Georgia flora, the writer became much interested in the means of dissemination of its modern allies, which in so far as they are known are worthy of enumeration. It has been shown that certain species of *Eugenia*, *Terminalia*, *Rhizophora*, *Pisonia*, and *Sapindus* have become adapted for dispersal through the agency of ocean currents, by specialization of their fruits or seeds, which have developed air chambers or woody husks for buoyancy, and practically impervious seed coverings for the exclusion of sea water from their vital parts. Everyone is familiar

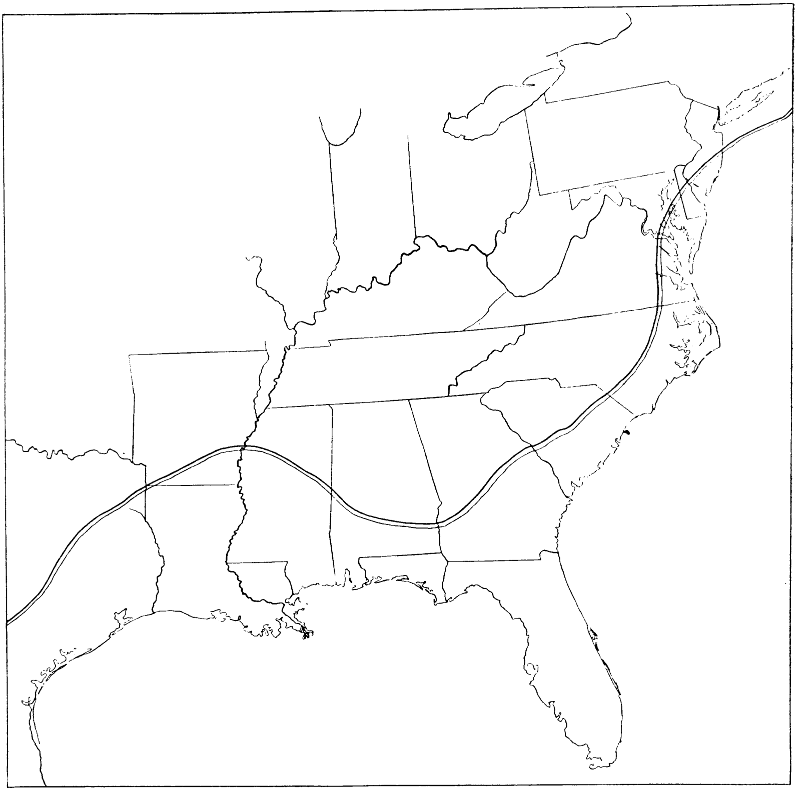

FIG. 2.—Sketch map showing the approximate shore line of the middle eocene sea in southeastern North America.

with the extreme specialization of the mangrove, which sends its germinating plantlets out into the world fully prepared to anchor themselves in water of the required depth, but the comparable specializations of the other members of these floras, though less in degree, are almost as effective, judging by the present geographical distribution of these genera, so that ocean currents must play a considerable rôle in distribution, despite the contrary opinion of DE

Candolle. Other members of the Claiborne flora may be supposed to have been distributed by fruit-eating birds. This seems clearly to apply to *Ficus* and probably to *Malapoenna*.

It can be readily shown that the existing flora of peninsular Florida, the Bahamas, Bermuda, etc., contains a large element which has been derived in comparatively recent geological times from the south. In the case of the Bahamas and Bermuda, almost their entire flora has had such an origin. If, however, we study geographical distribution in the light of historical geology, we find that the main elements of these modern floras were already in existence in the Middle Eocene, if not earlier. Experience teaches us that nearly all modern plant families, unless it be the most specialized forms like the orchids among the monocotyledons or the composites and their allies among the dicotyledons, were at some time more widely distributed than they are at present, and that the details of modern geographical distribution represent in a less degree the interchange of types between different areas than they do the greater or less degree of segregation of descendants of forms once spread over much wider areas. Uniformity appears to have been the rule during geologic history and not the exception.

From a study of the Claiborne flora it is evident that the main elements of the modern flora of tropical America reached as far northward in the Eocene as latitude 33 and probably much farther, and that in post-Eocene time they retreated southward. Dall,[1] from a study of the tertiary faunas of Florida, places a marked change in climate at the close of the Oligocene, and accounts for it by the elevation in the Florida area and the shifting to the eastward of the gulf stream with an inshore southerly flowing cold current.

Thus while the strictly modern movement of the subtropical flora along the course of the gulf stream has been from the south northward as the various coral islands of the Bahamas became evolved, this dispersion was preceded by a similar spread of the tropical flora on a much more extended scale during the early Tertiary.

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[1] Dall, Trans. Wagner Inst. 3:1549, 1550. 1903.